# A Least-Cost Model For Marketing Fresh Apples In the United States

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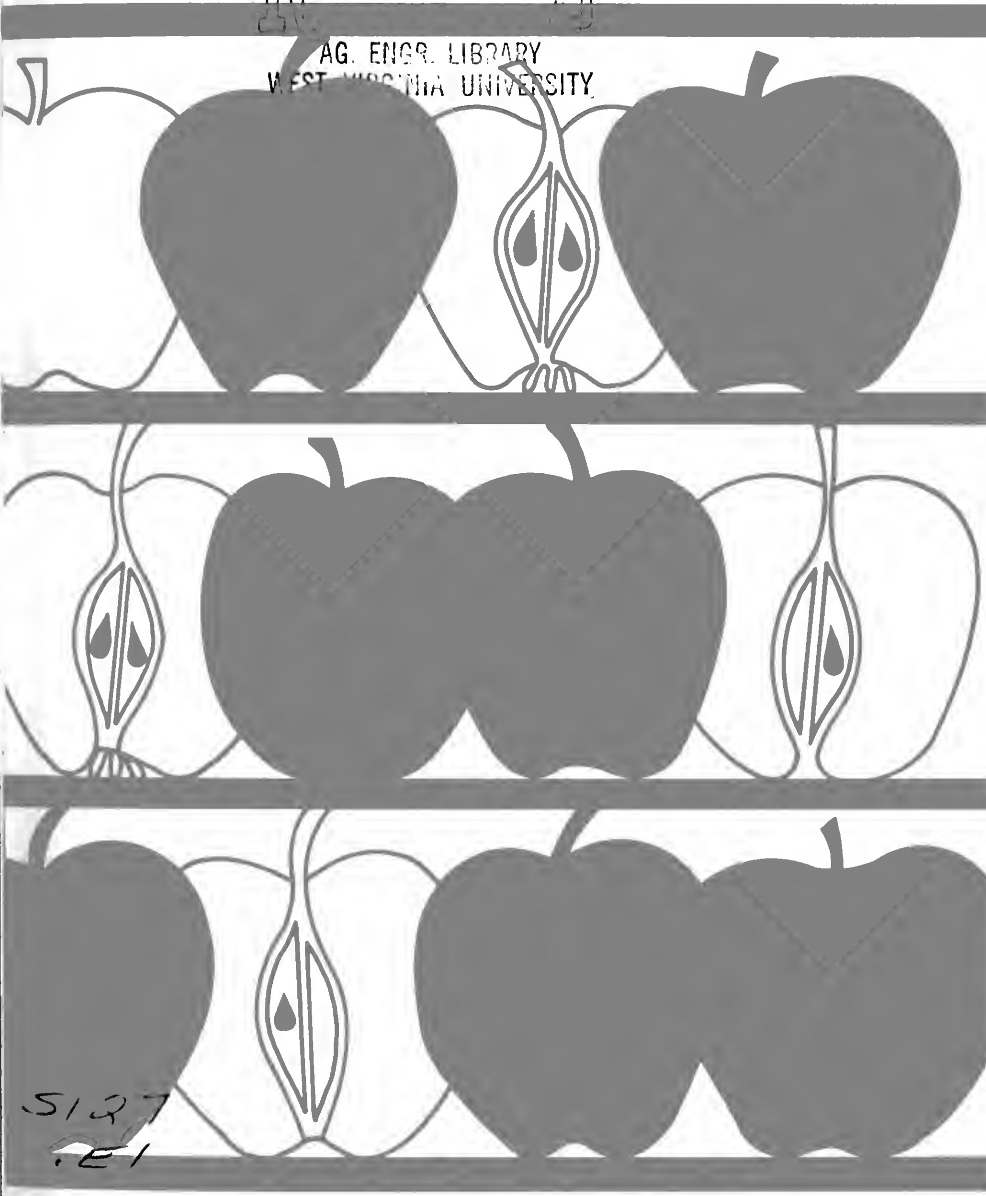



Virginia University • Agricultural Experiment Station

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## SUMMARY

Many changes have affected the market structure and competition in the fresh apple industry since the turn of the century. Some of these changes are increased yields, mechanization, improved transportation, and population shifts. In this study an attempt was made to develop a model which would determine the minimum cost of distributing the commercial fresh apple production over the United States.

In the analysis, the United States was divided into 22 consumption regions. Nine production regions were selected and these nine were dually classified with nine of the 22 consumption regions. Total regional consumption, truck rates, available cropland, and production costs were used to construct the original model. Alternative solutions of the model involved variations in total acreage, transportation rates, production costs, and projection of consumption to 1985.

The solution to the original model showed all nine production regions with unused acreages. New England, Washington, and Oregon, which had higher costs per unit of production than the other regions, did not enter into fresh apple production in this solution. The distribution pattern for production was generally east to west with the Virginia region having the largest number of acres in fresh apple production.

When acreage currently used in total apple production was used for the maximum acreage permitted for production (Alternative I), there was no change in the direction of flow or the regions engaged in fresh apple production. However, combined production and transportation costs in this solution were slightly higher than in the original model, because there was some reallocation of production with the Pennsylvania and Virginia regions producing more and the West Virginia region producing less.

In Alternative II, the maximum acreage permitted corresponded to the percentage of total apple production consumed fresh for each of the commercial production regions. The distribution pattern was basically west to east. Of the eight regions which produced, only the Washington region had unused acreage, but Washington was the largest producer in terms of acreage and production. Oregon was the only region in which no fresh apples were produced. Because this solution showed distribution and production patterns similar to those currently existing in the apple industry, it was used as a standard of comparison for the remaining alternatives.

The total acreage permitted in Alternative II was reduced 10 per cent for Alternative III. Since all regions except the Washington and Oregon regions used the entire acreage permitted in Alternative II, this 10 per cent decrease in available acreage caused a decrease in fresh apple production in all regions except the Washington and Oregon regions. This was compensated for by increased production in the Washington region while the Oregon region, again, produced no fresh apples. The distribution pattern for Alternative III was similar to that of Alternative II, but total production and transportation costs increased $6.9

million due to the higher production and transportation costs for apples produced in the Washington region.

In Alternative IV, all transportation costs were reduced 10 per cent, but there was little change from the distribution pattern of Alternative II. Acreages in fresh apple production in each region were the same as in Alternative II. A 10 per cent reduction in production costs in the Washington, Oregon, and California regions (Alternative V) did not change the level of production or west-to-east flow of fresh apples for Alternative II. In fact, the only difference in the two solutions was a $5.3 million decrease in total cost[1] in Alternative V.

In Alternative VI, regional consumption of fresh apples was projected to decrease in 21 of the 22 consumption regions by 1985.[2] This caused total fresh apple consumption to decrease despite increasing population. The distribution pattern in the solution was principally east to west, the Michigan region being the largest producer in terms of both acreage and cartons of apples. In this alternative, production decreased in the Washington and New England regions from Alternative II but remained constant in the other seven production regions.

Shadow prices on limited acreages[3] showed that of those regions with restricted acreages, an additional acre of production in the Michigan region would decrease total costs by the largest amount and an additional acre in the New England region would decrease total costs by the least amount. The Washington and Oregon regions had available acreage that wasn't used for apple production in all solutions, an indication that these two regions were at a competitive disadvantage relative to the other seven production regions when production, transportation costs, and consumption were considered. Shadow prices on the 22 consumption regions showed that, in general, as acreage was decreased, shadow prices increased and as costs or consumption decreased, shadow prices also decreased.

Costs of forced shipments from the West Virginia and Washington regions to all 22 consumption regions were determined. Generally, in alternatives where costs of forced shipments from Washington increased, there were simultaneous decreases in costs of forced shipments from West Virginia; the reverse was true for decreased shipments from Washington.

[1]Cost associated with total production in the U. S. and transportation of this production to points of consumption.

[2]Production and transportation costs as well as maximum acreage permitted were the same as in Alternative II.

[3]The amount by which total cost would be reduced if one additional acre were brought into production.

# A Least-Cost Model For Marketing Fresh Apples In The United States

Kathleen Brain and Robert L. Jack

Development and adoption of new technologies have changed the market structure and competition in the fresh apple industry since the turn of the century. For example, new varieties of apples, chemicals, and better management practices have made it possible to increase yields per acre. Increased mechanization of the apple industry and the high fixed costs associated with mechanization have led to gradual establishment of large scale farms with a high degree of specialization by region and varieties of apples. Refrigeration and improved transportation now allow producers to place high quality apples in any market in the world. The changes have increased competition among fresh apple producers in all states, regions, and nations.

Expanding population on the west coast and in a few southern states coupled with relatively stable population in the Northeast has caused a gradual shift in the population center toward the southwest. Because of this shift and declining per capita consumption, the demand for fresh apples is decreasing in the Northeast and is increasing in those areas where population is increasing.

## OBJECTIVES

The purpose of this study was to develop a model which would determine efficient distribution of commercial fresh apple production over the United States[4] and analyze the possible effects of alternative acreage capacities, transportation rates, and production costs as well as regional consumption projected to 1985.

## PROCEDURE

The United States was divided into 22 consumption regions, represented by one city selected on the basis of population concentration and proximity to the geographic center of the region (Figure 1). Nine production regions were defined and these were dually classified with nine of the 22 consumption regions. These production regions were represented by a city located in or near a major apple-producing area within the region (Figure 2).

[4]Alaska and Hawaii excluded.


Figure 1. Demarcation of 22 Consumption Regions and Points Representing Consumption


Figure 2. Demarcation of Nine Commercial Apple Production Regions and Points Representing Supply

A model was constructed using regional consumption, truck rates between all possible combinations of production and consumption regions, and yields, production costs, and maximum acreage permitted for each production region. Such a model is an attempt to bring together information which will reflect actual conditions in the fresh apple industry, and it should be able to give commercial apple producers in any area some indication of future trends. Once constructed, it is not difficult to change existing data in the model to reflect more closely a specific producer's transportation or production costs. Effects of anticipated changes in data used in the model (population increases, changes in apple consumption, yield or cost changes) can be analyzed by making appropriate changes in the model. These solutions will hopefully aid fresh apple producers in West Virginia and the Northeast in making decisions needed to stay competitive and profitable in the future.

## RESULTS

In the original model and first five alternatives, 1969 preliminary population estimates were multiplied by an adjusted per capita fresh apple consumption figure to arrive at estimated regional consumption. The maximum acreage permitted in the original model was the amount of total cropland available in each production region. Thus, in this case, it was possible that any region could have all of its cropland allocated to fresh apple production. The value of such a model is that regional fresh apple production is determined by production costs and transportation rates; the acreage allotment is so large that it is not a limiting factor.

In the solution to this model no production region used its entire cropland acreage for fresh apple production. The three regions with the highest production costs per unit of output—New England, Washington, and Oregon—had no acreage producing apples for the fresh market (Table 1).

Figure 3 shows the distribution pattern which minimized total transportation and production costs in this solution. The numbers on the arrows indicate the number of cartons in ten thousands being shipped to each consumption region. Underscored numbers indicate apples consumed in the same region they were produced in. The principal direction of shipments in this solution was from east to west. With the limitations imposed, California was the only fresh apple producer on the West Coast, and it supplied four consumption regions.

In this initial solution the Virginia region had the largest number of acres in fresh apple production (36,554 acres); however, due to higher yields, the Michigan region led in production. The total cost of production and transportation in the original model was $121.8 million.

The solution for this model was quite unlike conditions in the fresh apple industry today. In actuality Washington is an important supplier of fresh apples in the United States and makes shipments to points in the United States as far away as New York and Florida. The California region is a deficit region, relying

## TABLE 1
## LEAST-COST FRESH APPLE PRODUCTION BY REGION FOR THE ORIGINAL MODEL

| Production Region | Acreage in Fresh Apple Production[a] | Unused Acreage[a] | Total Production[b] (cartons) |
|---|---|---|---|
| | | | (ten thousands) |
| New England | 0 | 3,584,000 | 0 |
| New York | 30,022 | 8,897,978 | 1,011.7 |
| Pennsylvania | 29,727 | 7,803,273 | 1,007.7 |
| West Virginia | 25,100 | 2,817,900 | 850.8 |
| Virginia | 36,554 | 6,611,446 | 1,239.1 |
| Michigan | 32,914 | 10,411,086 | 1,372.5 |
| Washington | 0 | 14,926,000 | 0 |
| Oregon | 0 | 17,002,000 | 0 |
| California | 13,487 | 32,277,513 | 1,056.0 |
| TOTALS | 167,804 | | 6,537.9 |

[a]Rounded to the nearest whole number.

[b]Rounded to the nearest tenth.

on the Washington and Oregon regions for a portion of the fresh apples consumed in the state. Therefore, subsequent alterations were made in the model in order to arrive at a more realistic solution.

**Alternative I**

The maximum acreage permitted in Alternative I was the acreage devoted to apple production as reported in surveys between 1968 and 1970. Thus only the land in each region used for apple production recently, including apples for processing, was included in this alternative.

The solution to Alternative I was very similar to that of the original model. There was no change in the direction of flow or the regions engaged in fresh apple production (Table 2, Figure 4). In the West Virginia region, acreage in fresh apple production was reduced from 25,100 acres in the original model to 19,100 acres, the maximum acreage permitted for Alternative I. This reduction in the fresh apple supply was compensated for by increased production in the Virginia and Pennsylvania regions. There was a $20,000 increase in total costs over the original model. This increase was caused by higher transportation rates from the Pennsylvania region to Ohio and from the Virginia region to the Arkansas-Louisiana-Mississippi-Alabama region than from the West Virginia region to these two consumption regions. Production costs used in this study were the same for the West Virginia, Virginia, and Pennsylvania regions.

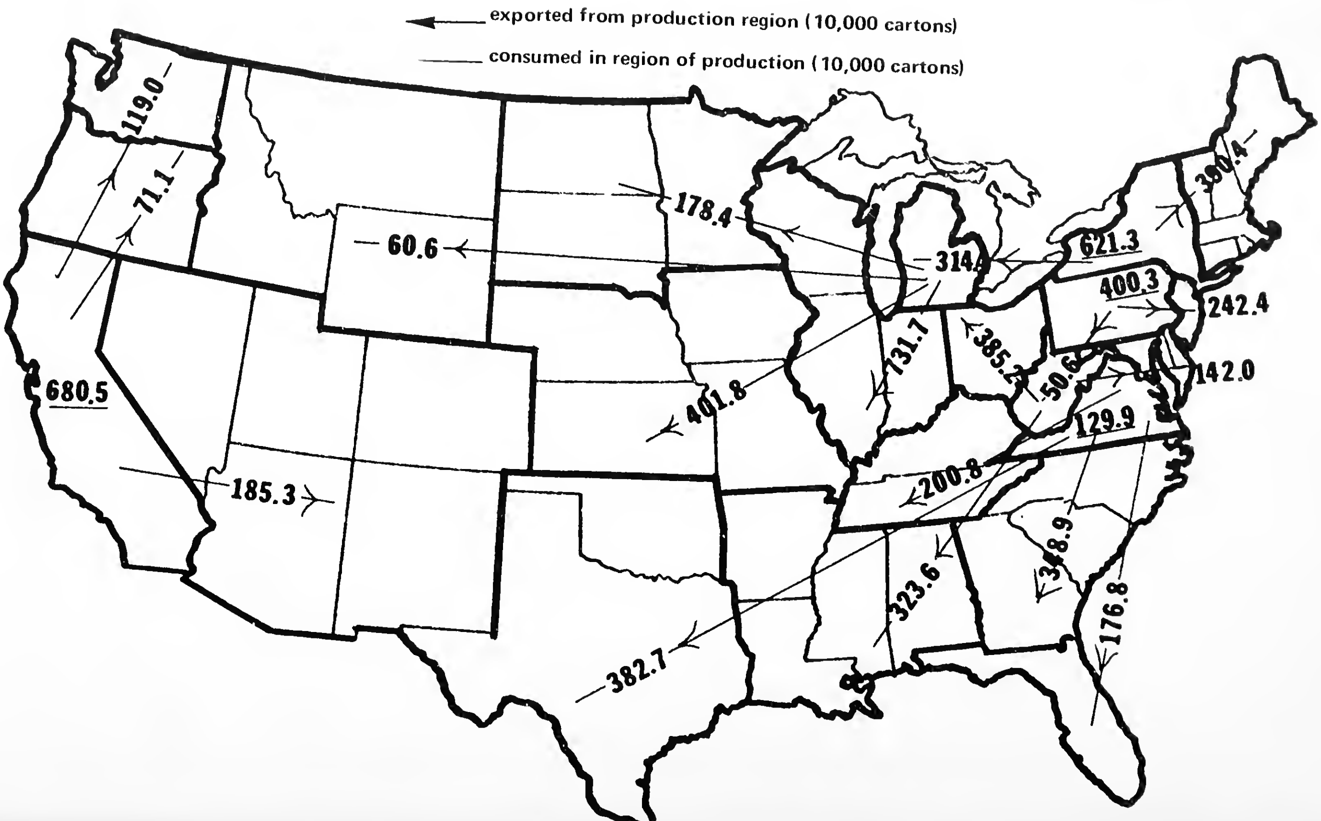


Figure 3. Least-cost Flow Pattern for the Original Model

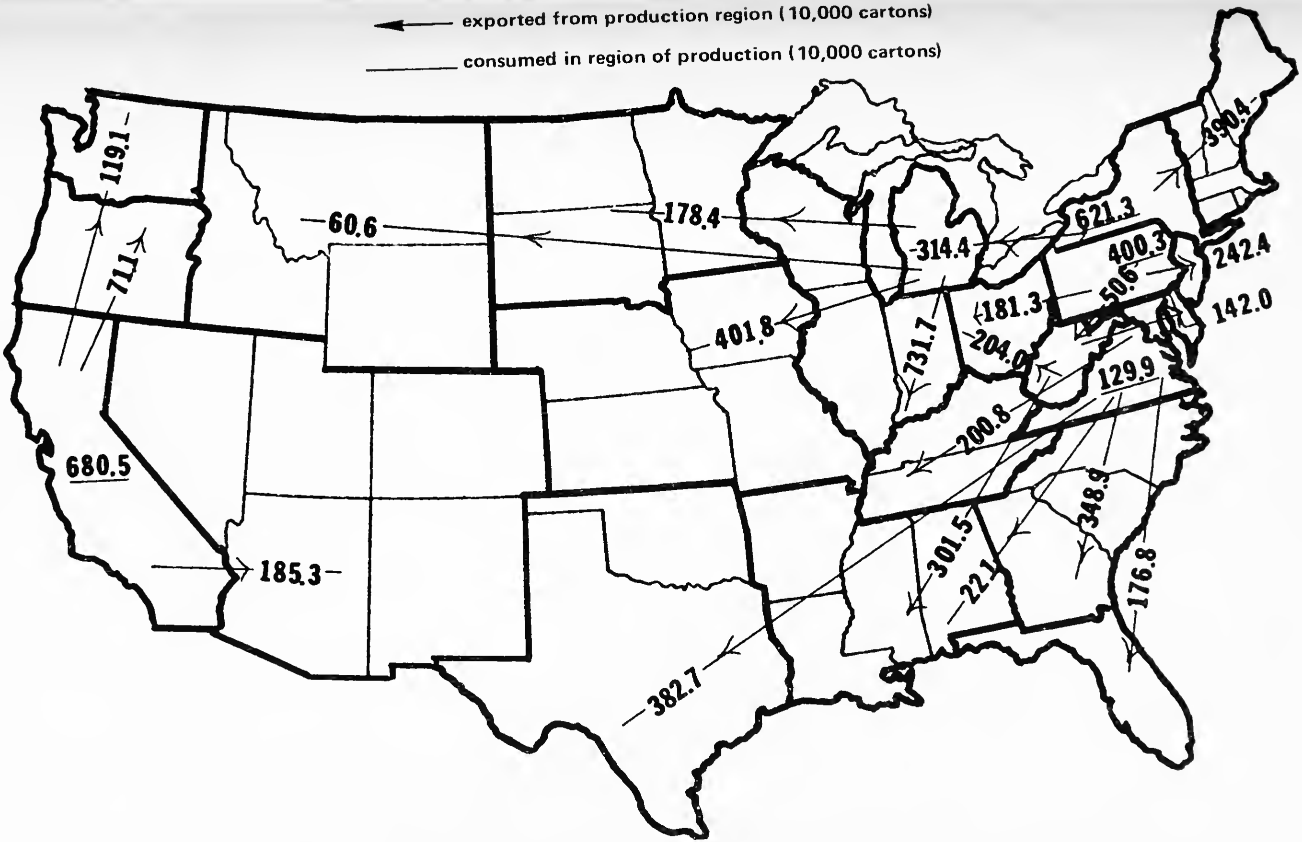


Figure 4. Least-cost Flow Pattern for Alternative I

# TABLE 2
## LEAST-COST FRESH APPLE PRODUCTION BY REGION FOR ALTERNATIVE I

| Production Region | Acreage in Fresh Apple Production[a] | Unused Acreage[a] | Total Production[b] (cartons) |
|---|---|---|---|
| | | | (ten thousands) |
| New England | 0 | 27,979 | 0 |
| New York | 30,022 | 44,354 | 1,011.7 |
| Pennsylvania | 35,074 | 3,484 | 1,189.0 |
| West Virginia | 19,100 | 0 | 647.5 |
| Virginia | 37,206 | 0 | 1,261.2 |
| Michigan | 32,914 | 43,086 | 1,372.5 |
| Washington | 0 | 92,244 | 0 |
| Oregon | 0 | 7,254 | 0 |
| California | 13,487 | 12,633 | 1,056.0 |
| TOTALS | 167,803 | | 6,537.9 |

[a]Rounded to the nearest whole number.

[b]Rounded to the nearest tenth.

The solution to Alternative I, like the original model solution, did not reflect present conditions in the fresh apple industry. This could be due to various factors, *e.g.,* inaccurate cost or other data used in the model or an actual situation of inefficient allocations of the fresh apple supplies. Because it is clear that all land used for apple production will not always bear fruit which will be offered for sale on the fresh market, an attempt was made to estimate acreage suitable for the fresh market.

### Alternative II

Maximum acreage permitted in this alternative was arrived at by multiplying the total acreage devoted to apple production for each production region by the per cent of total apple production consumed fresh in each region. The resulting distribution pattern was predominately west to east with almost all eastward shipments originating in the Washington region (Figure 5). Washington was also the leading production region in terms of acreage and output (Table 3). In Alternative I the California region had sufficient fresh apple production to supply other consumption regions, whereas in Alternative II apples had to be shipped into the California region to meet its consumption needs. Oregon was

## TABLE 3
## LEAST-COST FRESH APPLE PRODUCTION BY REGION FOR ALTERNATIVE II

| Production Region | Acreage in Fresh Apple Production[a] | Unused Acreage[a] | Total Production[b] (cartons) |
|---|---|---|---|
| | | | (ten thousands) |
| New England | 23,818 | 0 | 705.0 |
| New York | 30,256 | 0 | 1,019.6 |
| Pennsylvania | 10,256 | 0 | 347.7 |
| West Virginia | 9,315 | 0 | 315.8 |
| Virginia | 14,157 | 0 | 479.9 |
| Michigan | 30,294 | 0 | 1,263.2 |
| Washington | 44,771 | 21,396 | 1,929.5 |
| Oregon | 0 | 5,052 | 0 |
| California | 6,094 | 0 | 447.1 |
| TOTALS | 168,961 | | 6,537.8 |

[a]Rounded to the nearest whole number.

[b]Rounded to the nearest tenth.

the only production region which produced no fresh apples in this solution. Of the remaining eight production regions only Washington had unused acreage. The total production and transportation cost for Alternative II was $148.8 million.

In this solution both the Pennsylvania and West Virginia regions shipped apples to other consumption regions but did not supply consumption needs within their own regions. This probably was due to the location of the points representing production and consumption in each region and the method of predicting transportation rates. For example, although State College is about 50 miles further from Charleston than Berkeley Springs, the prediction equation for western shipments (Berkeley Springs to Charleston) yielded higher transportation rates than the southern route (State College to Charleston).

The solution to Alternative II fairly accurately represents the current west-to-east flow pattern in the fresh apple industry with eastern-produced apples being consumed east of the Mississippi River. Thus it appears that, given the present level of fresh apple production in each commercial production region, the supply is being distributed efficiently. Because the solution to Alternative II is similar to conditions in the apple industry today, it is used as a basis for comparison with the remaining alternatives.

exported from production region (10,000 cartons)

consumed in region of production (10,000 cartons)

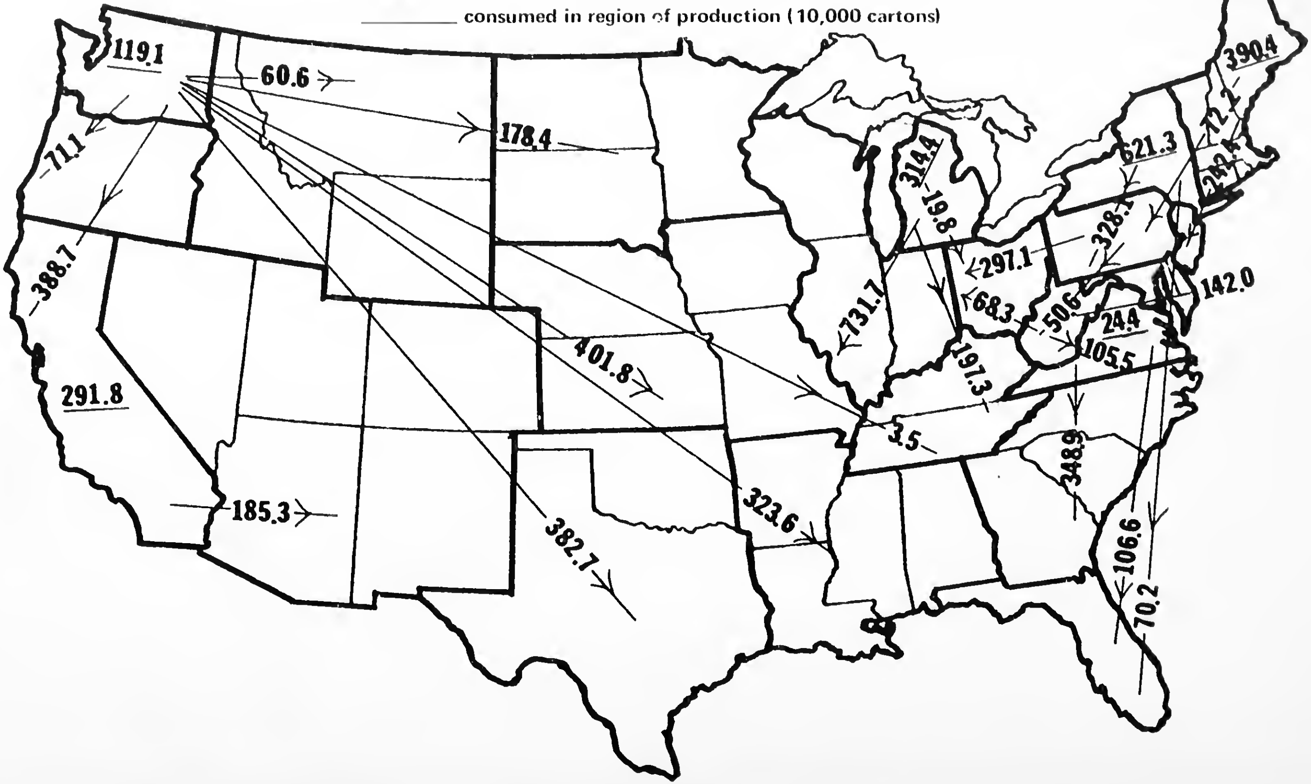


Figure 5. Least-cost Flow Pattern for Alternative II

**Alternative III**

Statistical reports indicate that total cropland, as well as acres planted in apples, has been decreasing for a number of years. In order to study the effects of further declines in acres planted in apple trees, the maximum acreage permitted for each region in Alternative II was reduced 10 per cent for Alternative III. In Alternative II only the Washington and Oregon regions had excess capacity for fresh apple production. Therefore, the loss of production capacity in the seven regions which were utilizing all the acreage available had to be compensated for by increased production in the Washington and/or Oregon regions. Thus, acreage devoted to fresh apple production in the Washington region increased from 44,771 acres in Alternative II to 55,463 acres in Alternative III (Table 4). The Oregon region did not produce fresh apples with either alternative.

There was very little change in the distribution pattern from Alternative II (Figure 6). The most notable change was the decreased quantity of apples shipped from the Pennsylvania and West Virginia regions to Ohio, and the reliance of Ohio on the Washington region for more than half the apples consumed fresh in the state. The total cost for Alternative III was $6.9 million greater than that of Alternative II.

## TABLE 4

## LEAST-COST FRESH APPLE PRODUCTION BY REGION FOR ALTERNATIVE III

| Production Region | Acreage in Fresh Apple Production[a] | Unused Acreage[a] | Total Production[b] (cartons) |
|---|---|---|---|
| | | | (ten thousands) |
| New England | 21,436 | 0 | 634.5 |
| New York | 27,230 | 0 | 917.7 |
| Pennsylvania | 9,230 | 0 | 312.8 |
| West Virginia | 8,384 | 0 | 284.2 |
| Virginia | 12,741 | 0 | 331.9 |
| Michigan | 27,265 | 0 | 1,136.9 |
| Washington | 55,463 | 4,087 | 2,390.3 |
| Oregon | 0 | 4,547 | 0 |
| California | 5,485 | 0 | 429.5 |
| TOTALS | 167,234 | | 6,537.8 |

[a]Rounded to the nearest whole number.

[b]Rounded to the nearest tenth.

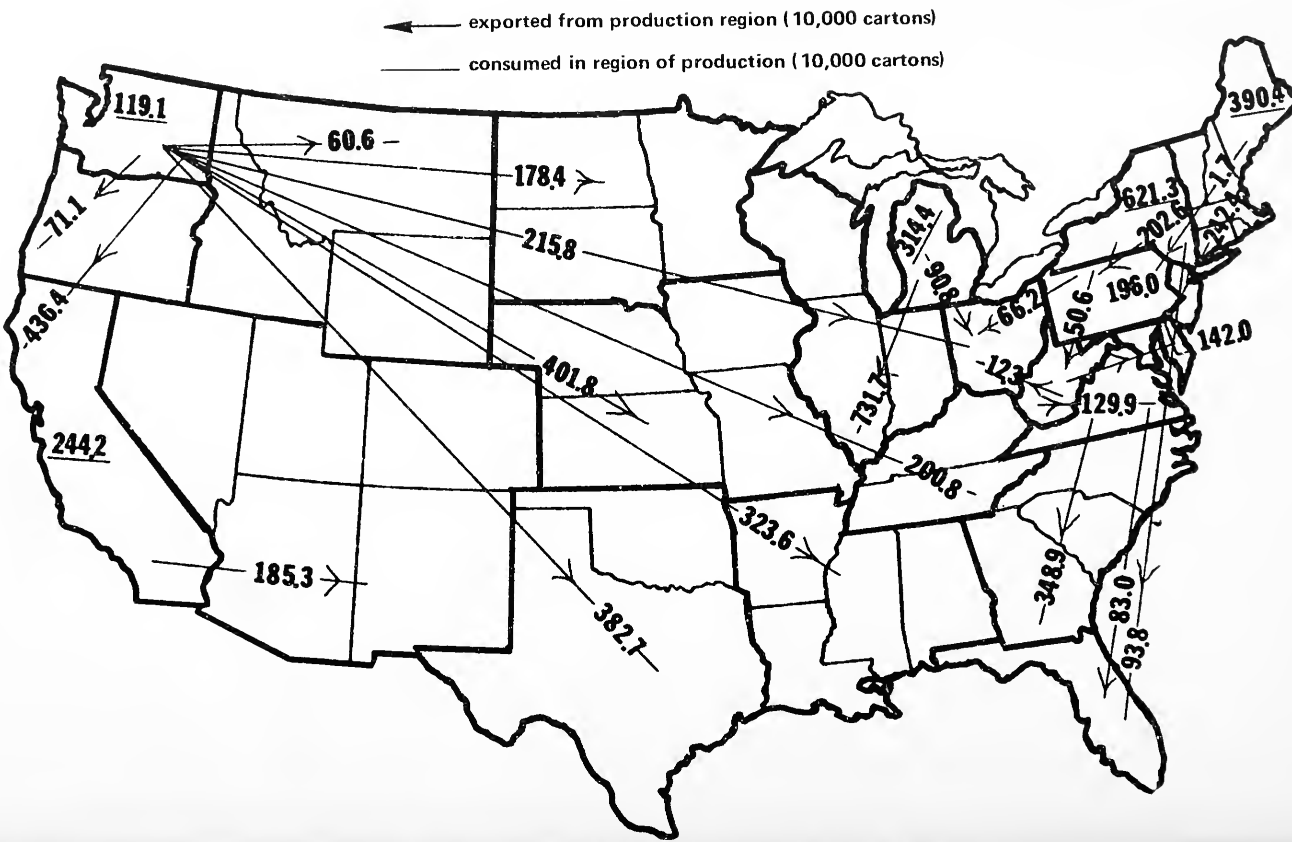


Figure 6. Least-cost Flow Pattern for Alternative III

It appears that as fewer acres are devoted to fresh apple production, the Washington region will increase fresh apple production to offset decreased production in the other commercial apple production regions.

### Alternative IV

Costs associated with transporting a commodity long distances restrict interregional competition and increase the location advantage of producers situated near densely populated market areas. Technological improvements which decrease transportation costs simultaneously reduce these location advantages and tend to increase interregional competition. Transportation rates for all regions were decreased 10 per cent for Alternative IV to study the effect of decreased transportation costs on interregional competition in the fresh apple industry. All other data used in this alternative were the same as used in Alternative II.

The decrease in transportation rates did not change production or affect significantly the flow pattern of fresh apples (Table 5, Figure 7) from Alternative II. In this alternative the Pennsylvania and Virginia regions did consume a larger portion of their production than in Alternative II. Shipments from the Virginia region to Florida decreased substantially, and shipments from the New York region to Florida increased. West Virginia apples which were

## TABLE 5

## LEAST-COST FRESH APPLE PRODUCTION BY REGION FOR ALTERNATIVE IV

| Production Region | Acreage in Fresh Apple Production[a] | Unused Acreages[a] | Total Production[b] (cartons) |
|---|---|---|---|
| | | | (ten thousands) |
| New England | 23,818 | 0 | 705.0 |
| New York | 30,256 | 0 | 1,019.6 |
| Pennsylvania | 10,256 | 0 | 347.7 |
| West Virginia | 9,315 | 0 | 315.8 |
| Virginia | 14,157 | 0 | 479.9 |
| Michigan | 30,294 | 0 | 1,263.2 |
| Washington | 44,771 | 21,396 | 1,929.5 |
| Oregon | 0 | 5,052 | 0 |
| California | 6,094 | 0 | 477.1 |
| TOTALS | 168,961 | | 6,537.8 |

[a]Rounded to the nearest whole number.

[b]Rounded to the nearest tenth.

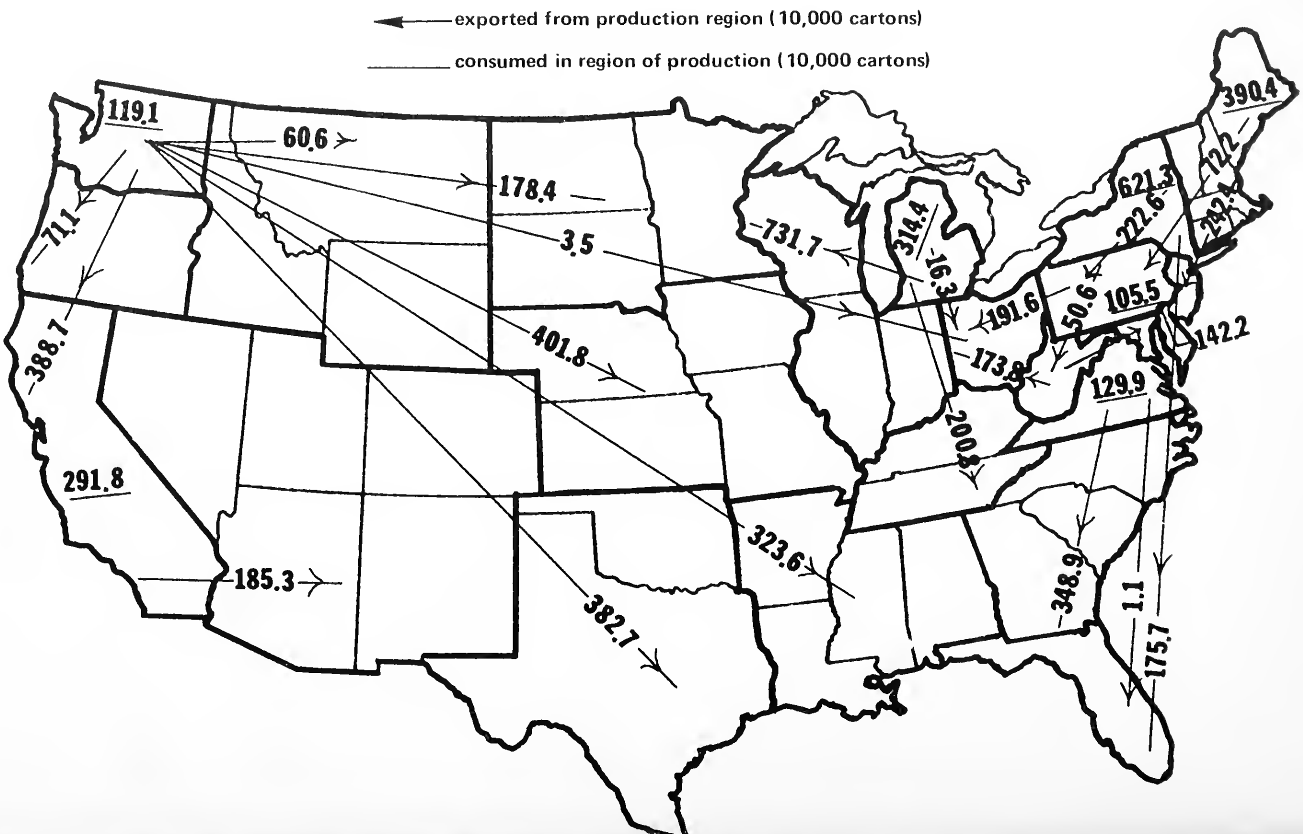


Figure 7. Least-cost Flow Pattern for Alternative IV

reviously shipped to Virginia were shipped to Ohio. A limited quantity of pples which was shipped from the Washington region to the Kentucky-ennessee region in Alternative II was shipped to Ohio in Alternative IV. From is solution it appears that a small reduction in transportation rates would have ery little effect on interregional competition in the fresh apple industry.

The total cost of production and transportation for Alternative IV was 145.6 million, which was $3.2 million less than Alternative II.

**lternative V**

There is some evidence that apples produced in Washington receive premium rices in the market, which may be due to consumer preference, product ifferentiation, or some other factors.

Although market prices were not used in this model, the premium prices njoyed by any region may be partially adjusted by decreasing production costs ccordingly in that region. In Alternative V the possibility of a price advantage or all western commercial fresh apple producers was explored by decreasing roduction costs 10 per cent in the Washington, Oregon, and California regions. ll other data used in this alternative were the same as those used in Alternative I.

The 10 per cent reduction in production costs in the Washington, Oregon, nd California regions did not change the level of production or direction of low of fresh apples (Table 6, Figure 8). The only difference between the olutions for Alternative II and Alternative V was a decrease in total cost of $5.3 nillion. Thus it appears that simulated higher margins in this alternative achieved hrough a reduction in production costs would not alter the competitive position f the western fresh apple producers.

**Alternative VI**

In Alternative VI regional consumption was projected to 1985 to assess the mpact of change in population and growth on the fresh apple industry. The lecrease in estimated unadjusted per capita consumption to 9.3 pounds for the Jnited States based on Economic Research Service figures was offset by ncreased population in only one region (Nevada-Utah-Colorado-Arizona-New Mexico), where total consumption would increase by 1.4 per cent. In all other onsumption regions, estimated consumption for 1985 was below that of 1969. The smallest decreases in regional consumption were in Florida and California vhere estimated consumption decreased by 5.1 and 7.4 per cent, respectively. All other data used in Alternative VI were the same as used in Alternative II.

The direction of flow in the optimum solution for Alternative VI was principally east to west (Figure 9). The level of production was the same as for Alternative II for all production regions except New England and Washington, where the levels of fresh apple production were reduced (Table 7). In this lternative the Washington region supplied fresh apples to only four con-sumption regions, including Washington, whereas in Alternative II it supplied

exported from production region (10,000 cartons)

consumed in region of production (10,000 cartons)


Figure 8.--Least-cost Flow Pattern for Alternative V

consumed in region of production (10,000 cartons)

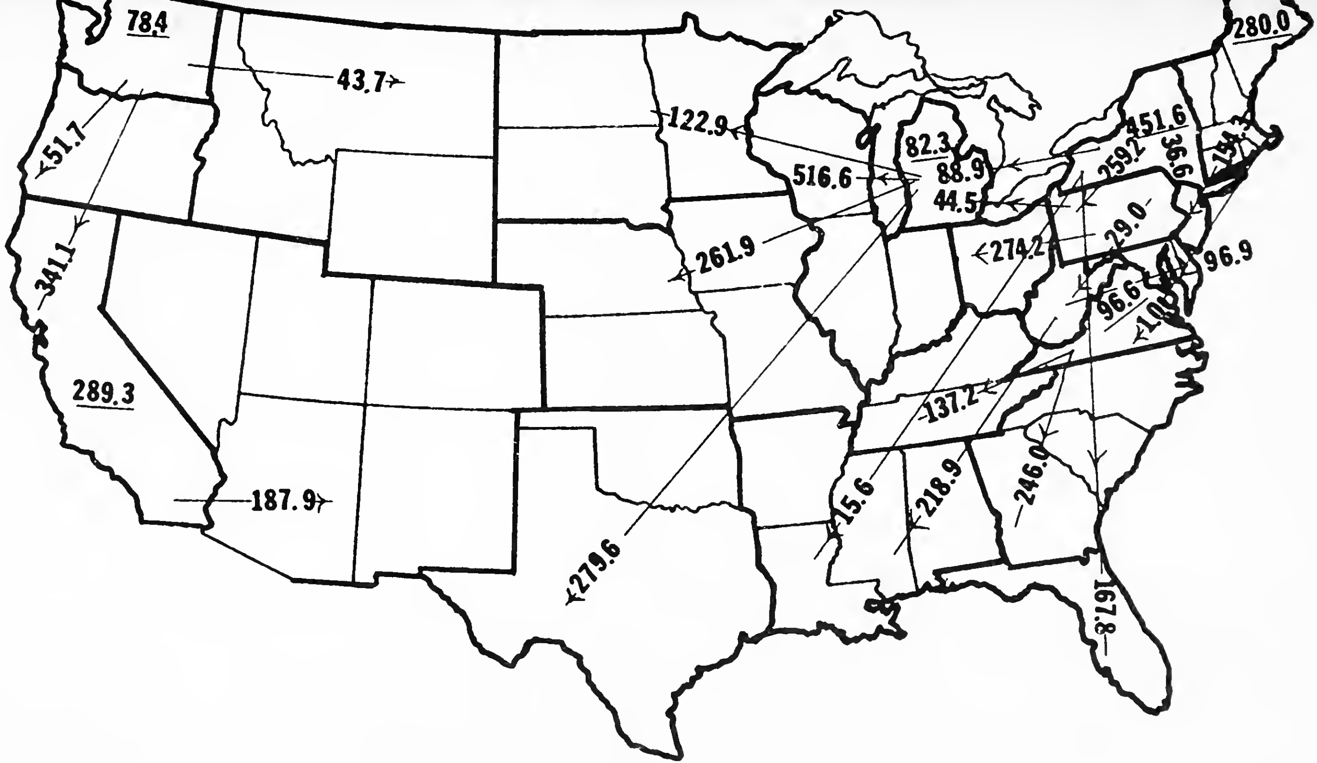


Figure 9. Least-cost Flow Pattern for Alternative VI

## TABLE 6
## LEAST-COST FRESH APPLE PRODUCTION BY REGION FOR ALTERNATIVE V

| Production Region | Acreage in Fresh Apple Production[a] | Unused Acreages[a] | Total Production[b] (cartons) |
|---|---|---|---|
| | | | (ten thousands |
| New England | 23,818 | 0 | 705.0 |
| New York | 30,256 | 0 | 1,019.6 |
| Pennsylvania | 10,256 | 0 | 347.7 |
| West Virginia | 9,315 | 0 | 315.8 |
| Virginia | 14,157 | 0 | 479.9 |
| Michigan | 30,294 | 0 | 1,263.2 |
| Washington | 44,771 | 21,396 | 1,929.5 |
| Oregon | 0 | 5,052 | 0 |
| California | 6,094 | 0 | 477.1 |
| TOTALS | 168,961 | | 6,537.8 |

[a]Rounded to the nearest whole number.

[b]Rounded to the nearest tenth.

nine consumption regions. Shipment of Michigan apples westward made i necessary for New York and Pennsylvania fresh apples to be shipped int Michigan to meet its regional consumption needs. The Kentucky-Tennesse region which received fresh apples from the Washington and Michigan regions i Alternative II, received its fresh apple supply from the Virginia region i Alternative VI.

The total production and transportation cost for this solution was $97.8 million. This was the least-cost alternative and can be explained by the fact that as consumption decreased, the eastern production regions and Michigan wer capable of meeting consumption needs in the eastern half of the United State and could do so at less cost than the Washington region could. The solution t this alternative suggested that a continued decline in aggregate fresh appl consumption would be felt by western fresh apple producers more rapidly tha by the producers in the eastern half of the United States.

### Shadow Prices

Shadow pricing of limited acreages is a technique used in linear pro gramming to determine the decrease in total cost that would occur when on additional acre is brought into production in a region with limited acreage at th expense of one acre in a region with unused acreage (Table 8). In the origina

TABLE 7
LEAST-COST FRESH APPLE PRODUCTION BY REGION FOR ALTERNATIVE VI

| Production Region | Acreage in Fresh Apple Production[a] | Unused Acreages[a] | Total Production[b] (cartons) |
|---|---|---|---|
| | | | (ten thousands) |
| New England | 14,709 | 9,109 | 435.3 |
| New York | 30,256 | 0 | 1,019.7 |
| Pennsylvania | 10,256 | 0 | 347.7 |
| West Virginia | 9,315 | 0 | 315.8 |
| Virginia | 14,157 | 0 | 479.8 |
| Michigan | 30,294 | 0 | 1,263.3 |
| Washington | 11,946 | 54,221 | 514.9 |
| Oregon | 0 | 5,052 | 0 |
| California | 6,094 | 0 | 477.2 |
| TOTALS | 127,027 | | 4,853.7 |

[a]Rounded to the nearest whole number.

[b]Rounded to the nearest tenth.

model unused acreage existed in all regions; therefore, no shadow prices were determined. In Alternative I only the West Virginia and Virginia regions produced at the maximum acreage permitted. Had one more acre of land been available in the Virginia region, it would not have been used for fresh apple production; therefore, total costs would not have decreased. The low shadow price for the West Virginia region indicated that utilization of more land would make little difference in total costs.

The shadow prices for each production region were similar for Alternatives II, III, IV, and V. In all four alternatives it appeared that among those regions with restricted acreage, an additional acre of production in the Michigan region would decrease total costs by the largest amount, while an additional acre in the New England region would be least beneficial in decreasing aggregate costs. Total consumption of fresh apples was less in Alternative VI than in the previous solutions. This alternative also had the least total cost of production and transportation of all solutions. Therefore, the shadow prices for Alternative VI were considerably less than for Alternatives II, III, IV, and V for all production regions except California. This relatively high shadow price for the California region in Alternative VI indicated that the competitive position for the California in the fresh apple industry might improve if aggregate consumption continues to decrease.

## TABLE 8

## SHADOW PRICES[a] ON LIMITED ACREAGES BY PRODUCTION REGION FOR THE ORIGINAL MODEL AND SIX ALTERNATIVES[b]

| Production Region | Basic Model | Alternative I | Alternative II | Alternative III | Alternative IV | Alternative V | Alternative VI |
|---|---|---|---|---|---|---|---|
| New England | – | – | $269.61 | $284.41 | $225.21 | $200.37 | – |
| New York | – | – | 553.07 | 569.92 | 499.15 | 474.24 | $232.64 |
| Pennsylvania | – | – | 588.36 | 605.31 | 534.12 | 509.06 | 296.53 |
| West Virginia | – | $3.39 | 591.75 | 608.70 | 537.51 | 512.45 | 306.70 |
| Virginia | – | 0[c] | 605.31 | 622.26 | 551.07 | 526.01 | 306.70 |
| Michigan | – | – | 685.92 | 706.77 | 615.03 | 588.37 | 351.97 |
| Washington | – | – | – | – | – | – | – |
| Oregon | – | – | – | – | – | – | – |
| California | – | – | 582.87 | 582.85 | 567.19 | 538.67 | 582.85 |

[a]Amount by which aggregate cost would be reduced if one acre of land were available for fresh apple production.

[b]Dash indicates that excess acreage existed, therefore no shadow price was determined.

[c]Alternative optimal solutions exist.

Oregon did not produce at all and Washington had unused acreage in each alternative, implying that these two production regions were at a competitive disadvantage relative to the other production regions in the model.

The shadow prices for the 22 consumption regions give the amount by which the total costs would increase if consumption were increased by one carton in any one consumption region (Table 9). In the original model and Alternative I the shadow prices were similar. Shadow prices in the western consumption regions were the highest, meaning it would be more costly to meet increased consumption by production in the western regions than elsewhere. Shadow prices were higher in Alternative II than in the basic model and Alternative I. This increase was probably due to scarce acreage in Alternative II, causing regions with higher per unit production costs to enter production.

In Alternative III, where acreage was restricted further, shadow prices increased in those consumption regions which were supplied by production regions east of the Mississippi and remained constant in those consumption regions supplied by the Washington and California regions. The shadow prices remained constant for the latter group because the Washington region had unused acreage available for fresh apple production whereas the production regions east of the Mississippi River were already producing at their maximum acreage constraints.

The decrease in transportation rates of 10 per cent in Alternative IV lowered all shadow prices from those given in Alternative II. This was expected, since all production regions could supply fresh apples at less cost than in Alternative II.

In Alternative V production costs on the west coast were decreased by 10 per cent. Any increase in consumption would be supplied by western producers and the decrease in their costs would decrease shadow prices for all consumption regions to which they would ship fresh apples.

In Alternative VI consumption was projected to 1985. Total consumption was less than in the other alternatives and because of this the New England region, which had the highest per unit production cost in the eastern half of the United States, had excess acreage. This unused acreage in the New England region caused all consumption regions which were supplied by eastern producers in Alternative VI to have lower shadow prices than in Alternative II. Any increase in consumption could be supplied by the New England region, which had lower per unit production costs than the Washington or Oregon regions. The four consumption regions which were supplied by western producers in Alternative VI had shadow prices equal to those in Alternative II.

**Costs of Forced Shipment**

The costs associated with forcing shipment from any production region to any consumption region show the amount by which the total cost would increase with distance of shipment since mileage and transportation costs are postively correlated.

TABLE 9

SHADOW PRICES[a] ON CONSUMPTION BY CONSUMPTION REGION FOR THE ORIGINAL MODEL AND SIX ALTERNATIVES

| Consumption Region | Basic Model | Alternative I | Alternative II | Alternative III | Alternative IV | Alternative V | Alternative VI |
|---|---|---|---|---|---|---|---|
| 1 New England | $1.74 | $1.74 | $3.19 | $3.24 | $3.02 | $2.96 | $2.28 |
| 2 NY | 1.69 | 1.69 | 3.33 | 3.38 | 3.14 | 3.10 | 2.38 |
| 3 PA | 1.64 | 1.64 | 3.38 | 3.43 | 3.19 | 3.14 | 2.43 |
| 4 NJ | 1.68 | 1.68 | 3.35 | 3.40 | 3.17 | 3.12 | 2.44 |
| 5 DE-MD | 1.52 | 1.53 | 3.27 | 3.32 | 3.09 | 3.04 | 2.43 |
| 6 WV | 1.73 | 1.73 | 3.47 | 3.52 | 3.27 | 3.24 | 2.61 |
| 7 VA | 1.64 | 1.64 | 3.43 | 3.49 | 3.24 | 3.20 | 2.55 |
| 8 NC-SC-GA | 1.70 | 1.70 | 3.49 | 3.54 | 3.29 | 3.26 | 2.61 |
| 9 FL | 1.82 | 1.82 | 3.61 | 3.66 | 3.40 | 3.38 | 2.66 |
| 10 MI | 1.83 | 1.83 | 3.51 | 3.56 | 3.30 | 3.28 | 2.71 |
| 11 WI-IL-IN | 1.74 | 1.74 | 3.39 | 3.44 | 3.20 | 3.16 | 2.59 |
| 12 OH | 1.79 | 1.80 | 3.54 | 3.59 | 3.33 | 3.30 | 2.68 |
| 13 KY-TN | 1.84 | 1.84 | 3.59 | 3.59 | 3.38 | 3.36 | 2.75 |
| 14 AR-LA-MS-AL | 1.94 | 1.95 | 3.49 | 3.49 | 3.37 | 3.26 | 2.85 |
| 15 ND-SD -MN | 1.89 | 1.89 | 3.22 | 3.22 | 3.13 | 2.98 | 2.74 |
| 16 NE-IA-KS-MO | 1.97 | 1.97 | 3.29 | 3.29 | 3.19 | 3.06 | 2.82 |
| 17 OK-TX | 2.06 | 2.06 | 3.44 | 3.44 | 3.33 | 3.20 | 2.94 |
| 18 MT-ID-WY | 2.28 | 2.28 | 2.84 | 2.84 | 2.79 | 2.60 | 2.84 |
| 19 NV-UT-CO-AZ-NM | 2.32 | 2.32 | 3.07 | 3.07 | 2.99 | 2.84 | 3.07 |
| 20 WA | 2.33 | 2.33 | 2.56 | 2.56 | 2.54 | 2.32 | 2.56 |
| 21 OR | 2.25 | 2.25 | 2.58 | 2.58 | 2.56 | 2.34 | 2.58 |
| 22 CA | 2.17 | 2.17 | 2.29 | 2.92 | 2.86 | 2.68 | 2.96 |

The costs of forcing shipment of West Virginia fresh apples increased from the original model to Alternative I, as the West Virginia region had no unused acreage in Alternative I (Table 10).

Costs of forced shipment were the same in Alternatives II and V and were generally higher than in the original model and Alternative I due to decreases in the maximum acreage permitted. In Alternative III costs of forced shipment were the same as those in Alternative II except for those consumption regions which were supplied by the Washington region. This was so because acreage in fresh apple production was decreased in the West Virginia region but increased in the Washington region.

All costs were lower in Alternative IV than in Alternative II, reflecting the 10 per cent decrease in transportation costs in Alternative IV. In Alternative VI costs of forced shipment from the West Virginia region were higher than in Alernative II and lower for consumption regions which were supplied by western producers in Alternative II. In Alternative VI the West Virginia region appears less competitive with the eastern producers—probably due to the availability of excess acreage in the New England region—and more competitive with the western producers. The decrease in cost of forced shipment to the western regions can be explained partially by the shipment of the West Virginia region fresh apples to more distant consumption regions in Alternative VI than Alternative II; therefore, the increased cost of shipping to the western consumption regions was less than in Alternative II.

The costs of forced shipment from the Washington region to other consumption regions were very similar for the original model and Alternative I (Table 11). The Washington region did not produce fresh apples in either case. In Alternatives II and V the costs of forced shipment were the same. These costs were much less than costs in the first two solutions because the Washington region was producing heavily in Alternatives II and V and any increase in consumption would have been supplied by the Washington region. In Alternative III, due to a decrease in the maximum acreage constraints in all production regions, the Washington region produced more apples than previously and the costs of forced shipment decreased from those of Alternative II.

The costs of forced shipment from the Washington region increased in Alternative IV, in which the effect of a 10 per cent decrease in all transportation costs was analyzed. It appears that if transportation costs decrease, the Washington region will become less competitive with the eastern producers. In Alternative VI, where consumption was projected to 1985, the costs of forced shipment from the Washington region were higher than in Alternative II. As total consumption decreased, the Washington region with its comparatively high per unit production costs was not able to compete with the eastern producers. The Washington region fresh apple production in Alternative VI was less than half that of Alternative II.

## TABLE 10

### COST OF FORCING SHIPMENT OF ONE CARTON OF APPLES FROM WEST VIRGINIA TO ANY CONSUMPTION REGION FOR THE ORIGINAL MODEL AND SIX ALTERNATIVES[a]

| Consumption Region | Basic Model | Alternative I | Alternative II | Alternative III | Alternative IV | Alternative V | Alternative VI |
|---|---|---|---|---|---|---|---|
| 1 New England | $ .16 | $ .18 | $ .46 | $ .46 | $ .41 | $ .46 | $ .53 |
| 2 NY | .01 | .02 | .11 | .11 | .10 | .11 | .22 |
| 3 PA | 0[b] | .01 | .01 | .01 | .01 | .01 | .12 |
| 4 NJ | .01 | .02 | .09 | .09 | .07 | .09 | .16 |
| 5 DE-MD | — | — | — | — | — | — | — |
| 6 WV | .06 | .07 | .07 | .07 | .06 | .07 | .09 |
| 7 VA | .04 | .05 | — | — | 0[b] | — | .04 |
| 8 NC-SC-GA | .09 | .10 | .05 | .05 | .05 | .05 | 09 |
| 9 FL | .10 | .11 | .06 | .06 | .05 | .06 | .17 |
| 10 MI | .06 | .07 | .13 | .13 | .12 | .13 | .09 |
| 11 WI-IL-IN | .15 | .16 | .25 | .25 | .22 | .25 | .21 |
| 12 OH | — | — | — | — | — | — | .02 |
| 13 KY-TN | .06 | .07 | .06 | .11 | .05 | .06 | .06 |
| 14 AR-LA-MS-AL | — | — | .20 | .25 | .10 | .20 | — |
| 15 ND-SD-MN | .15 | .16 | .57 | .62 | .43 | .57 | .21 |
| 16 ME-IA-KS-MO | .17 | .18 | .60 | .65 | .46 | .60 | .23 |
| 17 OK-TX | .06 | .07 | .43 | .48 | .30 | .43 | .09 |
| 18 MT-ID-WY | .08 | .09 | 1.27 | 1.32 | 1.06 | 1.27 | .43 |
| 19 NV-UT-CO-AZ-NM | .09 | .10 | 1.09 | 1.14 | .90 | 1.09 | .25 |
| 20 WA | .23 | .24 | 1.75 | 1.80 | 1.49 | 1.75 | .91 |
| 21 OR | .33 | .34 | 1.75 | 1.80 | 1.49 | 1.75 | .91 |
| 22 CA | .36 | .37 | 1.36 | 1.41 | 1.14 | 1.36 | .52 |

[a] Dash indicates variables in the basis; costs are given only for nonbasis variables.

CONSUMPTION REGION FOR THE ORIGINAL MODEL AND SIX ALTERNATIVES[a]

| Consumption Region | Basic Model | Alternative I | Alternative II | Alternative III | Alternative IV | Alternative V | Alternative VI |
|---|---|---|---|---|---|---|---|
| 1 New England | $1.89 | $1.89 | $ .66 | $ .61 | $ .68 | $ .66 | $1.57 |
| 2 NY | 2.08 | 2.08 | .66 | .61 | .69 | .66 | 1.61 |
| 3 PA | 2.12 | 2.12 | .61 | .56 | .64 | .61 | 1.56 |
| 4 NJ | 2.08 | 2.08 | .64 | .59 | .66 | .64 | 1.55 |
| 5 DE-MD | 2.24 | 2.23 | .72 | .67 | .74 | .72 | 1.56 |
| 6 WV | 1.78 | 1.78 | .27 | .22 | .33 | .27 | 1.13 |
| 7 VA | 2.02 | 2.02 | .46 | .41 | .49 | .46 | 1.34 |
| 8 NC-SC-GA | 1.81 | 1.81 | .25 | .20 | .31 | .25 | 1.13 |
| 9 FL | 1.64 | 1.64 | .08 | .03 | .15 | .08 | 1.03 |
| 10 MI | 1.58 | 1.58 | .13 | .08 | .21 | .13 | .93 |
| 11 WI-IL-IN | 1.47 | 1.47 | .05 | 0[b] | .27 | .05 | .85 |
| 12 OH | 1.57 | 1.56 | .05 | — | — | .05 | .91 |
| 13 KY-TN | 1.52 | 1.52 | — | — | .09 | — | .84 |
| 14 AR-LA-MS-AL | 1.32 | 1.31 | — | — | — | — | .64 |
| 15 ND-SD-MN | 1.10 | 1.10 | — | — | — | — | .48 |
| 16 NE-IA-KS-MO | 1.09 | 1.09 | — | — | — | — | .47 |
| 17 OK-TX | 1.15 | 1.15 | — | — | — | — | .50 |
| 18 MT-ID-WY | .33 | .33 | — | — | — | — | — |
| 19 NV-UT-CO-AZ-NM | .54 | .54 | .02 | .02 | .02 | .02 | .02 |
| 20 WA | — | — | — | — | — | — | — |
| 21 OR | .10 | .10 | — | — | — | — | — |
| 22 CA | .52 | .52 | — | — | — | — | — |

[a]Dash indicates variables in the basis: costs are given only for nonbasis variables.

[b]Alternate optimal solutions exist.

## CONCLUSIONS AND IMPLICATIONS

In the solution to the original model where acreage constraints were so large they were not a limiting factor, the Washington region, which is presently the largest commercial apple producing state, did not produce at all. In order to arrive at a solution which reflected present conditions in the fresh apple industry (Alternative II) acreage in all production regions was restricted so that the Washington region was forced into production to help meet aggregate consumption needs. Adjustments for the premium price paid for certain varieties of Washington-produced apples did not improve the competitive position of the Washington region relative to the other commercial apple production regions within the adjustment limits used.

The results indicate that efficiency in the fresh apple industry could be improved. However, Alternative II indicated that, given the present level of fresh apple production in each commercial region, the supply is being distributed relatively efficiently. If the regional level of production were changed in the direction of the original model solution, total cost would be reduced. This alternative would involve a decrease in fresh apple production in the Washington, Oregon, and New England regions, and an increase in fresh apple production in all the other commercial regions used in the study.

There has been a general trend for per unit production costs to increase in the Washington region, and a recent study indicated that returns did not cover costs in 1965. Apple production in the Oregon region has decreased over the last 50 years, but pear production has increased substantially. While apples are important contributors to the New England economy, recent increases in peach plantings may signal a gradual shift of emphasis in that region. These trends suggest that fresh apple producers in the Washington, Oregon, and New England regions might be considering downward adjustment of production.

Shadow prices indicate that additional acreage in the Michigan region would be most valuable in reducing total costs. Additional production in the Michigan region could be used to supply the prairie states at less cost than at present with the Washington region supplying these states. The high shadow price for an additional acre in the California region in Alternative VI implies that the California region has the economic potential to become important in the fresh apple industry. But, due to a climate more favorable for production to match the increasing consumption of citrus fruits, it is doubtful that fresh apple production will increase significantly in that region.

Costs of production seem to be more important than transportation rates in determining the location of fresh apple production. High per unit production costs appeared directly related to unused acreage.

Adjustments made in the fresh apple supply in one region affect producers in all other regions. At a time when supply seems to be increasing more rapidly than demand, the results of this study indicate that West Virginia is in a good competitive position to maintain its share of the fresh apple market.

Although this study assumed that apples are a homogeneous product, statistical reports indicate that consumers differentiate between Washington apples and those grown elsewhere. This consumer preference may allow Washington to enjoy premium prices and higher levels of production than would exist under purely competitive conditions. In cases where decreasing consumption necessitates downward production adjustments, such adjustments would more likely take place in production regions other than Washington if consumers continue to differentiate between Washington-grown apples and those produced in other regions.